DTU Library

Design study of a 10 MW MgB2 superconductor direct drive wind turbine generator

Abrahamsen, Asger Bech; Magnusson, Niklas; Liu, Dong; Stehouwer, Ewoud ; Hendriks, Ben; Polinder, Henk

Publication date:
2014

PO.ID 336

Design study of a 10 MW MgB_2 superconductor direct drive wind turbine generator

Asger B. Abrahamsen[1], Niklas Magnusson[2], Dong Liu[3], Ewoud Stehouwer[4], Ben Hendriks[4] and Henk Polinder[3]

DTU Wind Energy[1], SINTEF Energy Research[2], Delft University of Technology[3] and DNV-GL[4]

DTU

Abstract

A design study of a 10 MW direct drive wind turbine generator based on MgB_2 superconducting wires is presented and the cost of the active materials of the generator is estimated to be between 226 €/kW and 84 €/kw, which is lower than the threshold values of 300 €/kW of the INNWIND.EU project. A nacelle structure with a front-mounted generator is presented for further investigation of the integration of such a superconducting generator into offshore turbines with power ratings considerably larger than 10 MW.

Nacelle and Generator

Motivation:

The INNWIND.EU project is investigating the feasibility of superconducting direct drive generators for offshore turbines ranging up to 20 MW [1]. A king-pin nacelle design is proposed as template for comparing different generators in terms of cost and cost of energy. Features of the drive train are outlined below:

Nacelle

- Static King-Pin and two main bearings supporting hub
- P = 10 MW, T = 10.6 MNm @ 9.65 rpm

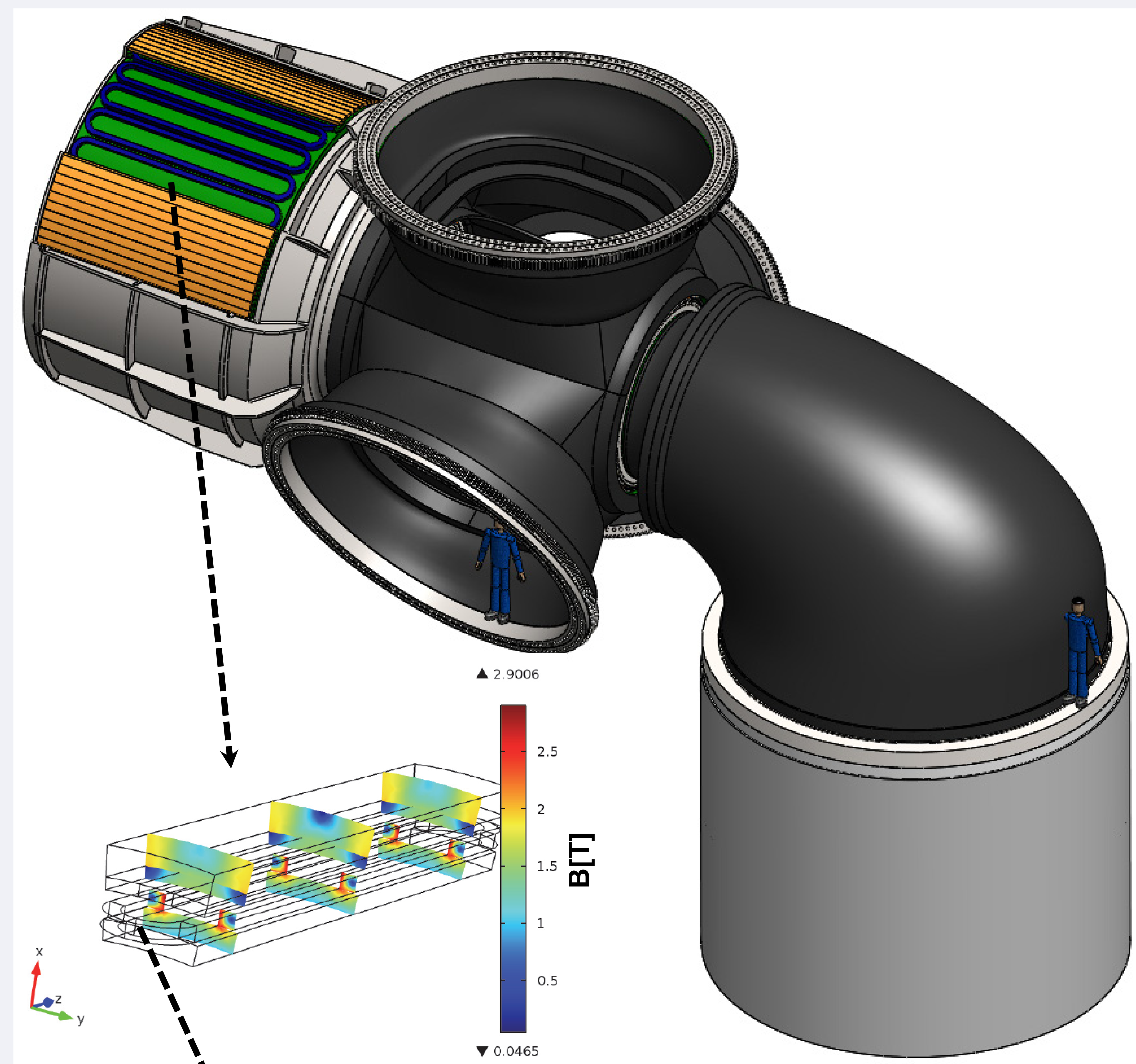
Generator

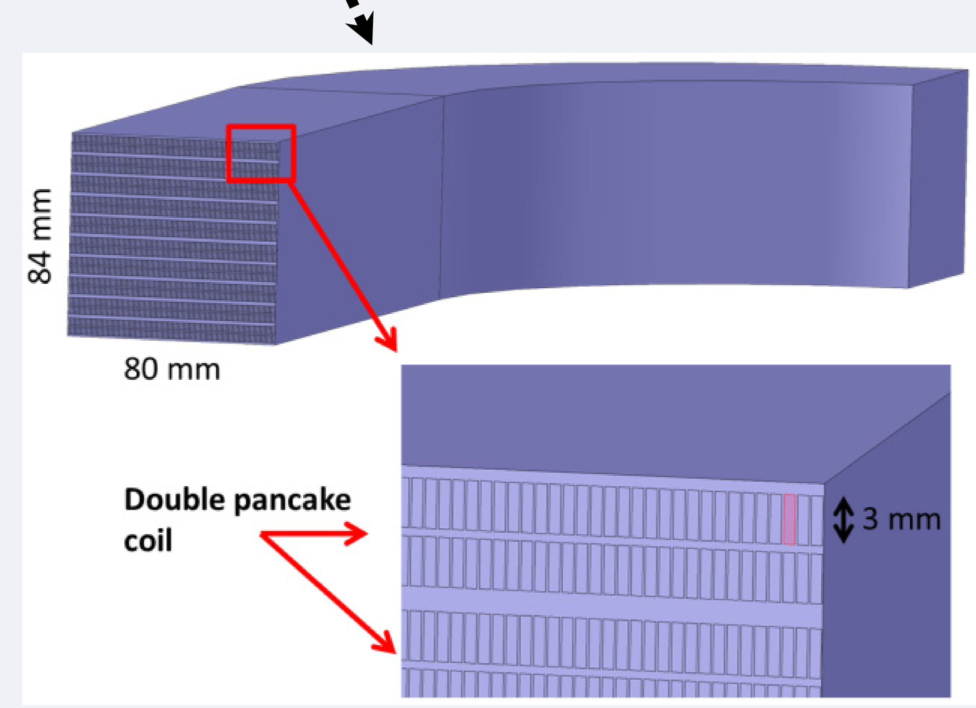
- Superconducting field coils and conventional armature winding of Cu
- Air-cored armature windings and magnetic steel shielding
- Non-magnetic support of rotor coils
- Static superconducting field coils and rotating armature with slip ring
- Static cryostat and cryogenic cooling system
- Full rated power electronics
- D = 5.8 m & L = 3.1 m to match the hub
- 32 poles & f = 2.6 Hz
- B_g = 1.5 T, A_S = 100 kA/m & F_d = 75 kN/m2

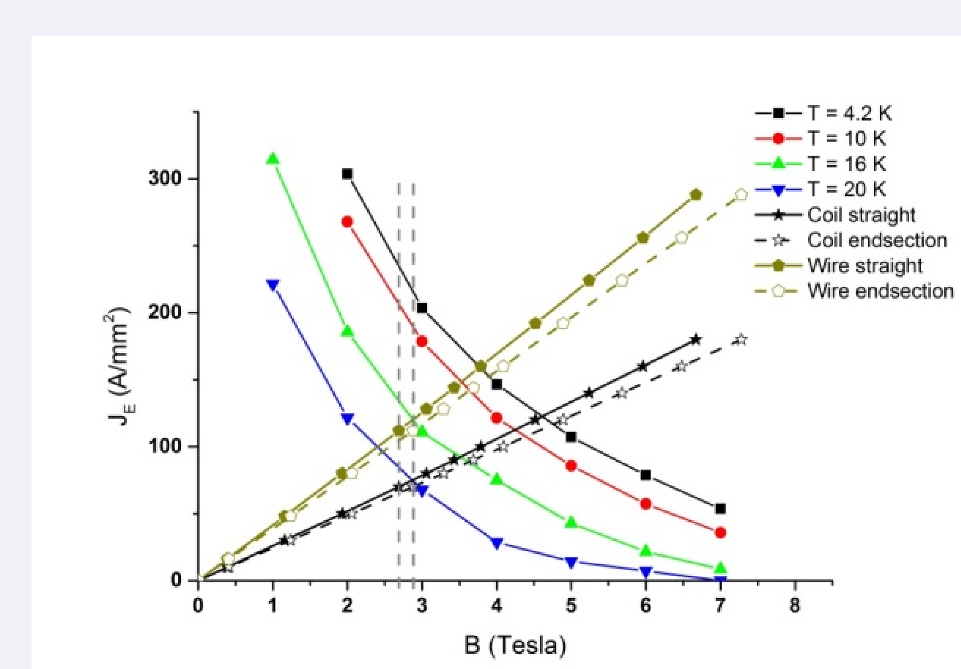
Rotor field coils

- MgB_2 superconducting tape (3.0 mm x 0.7 mm) @ 4 ($\rightarrow$ 1) €/m [2]
- T_C = 39 K & minimum bending diameter = 0.15 m
- Race track coil as stack of 10 double pan cake coils (D = 0.3 m)

$R_{Fe\ out}$ [m]	2.94	Torque [MNm]	10.6
$R_{Armature\ out}$ [m]	2.79	Speed [rpm]	9.65
$R_{Armature\ in}$ [m]	2.73	Poles [2p]	32
$R_{Supercond\ out}$ [m]	2.69	Frequency [Hz]	2.57
$R_{Supercond\ in}$ [m]	2.59	$B_{air\ gap}$ [T]	1.5
$L_{generator}$ [m]	3.1	Arm. loading [A/m]	10^5
R_{End} [m]	0.15	Arm. Fill [%]	50
W_{coil} [mm]	84	Shear stress [kN/m²]	75
H_{coil} [mm]	80	Efficiency [%][1]	97.7
$L_{SC\ single\ pancake}$ [m]	740.9	J_{coil} [A/mm²]	70 @ 3 Tesla
$L_{SC\ double\ pancake}$ [m]	1481.7	J_{tape} [A/mm²]	113 @ 3 Tesla
$L_{SC\ Race\ track\ coil}$ [km]	14.82	M_{Cu} [kg]	19415
$L_{SC\ total}$ [km]	474.2	M_{Fe} [kg]	24998
Tape unit cost [€/m]	4 ($\rightarrow$ 1)	M_{active} [kg]	52331
SC cost [k€]	1897 ($\rightarrow$ 474)	Cost Cu [€]	291234
$M_{Superconductor}$ [kg]	7918.1	Cost Fe [€]	74994
$M_{cryostat+cooler}$ [kg]	TBD	Cost total [k€]	2263 ($\rightarrow$ 840)
Cost cryostat	TBD	Cost / cap. [€/kW]	226 ($\rightarrow$ 84)







Discussion

- Load line of field coil: J_E = 70 A/mm² in 2.9 T $\rightarrow$ $T_{operation}$ ~ 10-15 K [3]
- Cost of active material (SC, Cu & Fe) ~ 226 €/kW ($\rightarrow$ 84 €/kW)
- < 300 €/kW threshold: 20 % for drive train of 1.5 M€/MW of turbine cost

Conclusions

A 10 MW superconducting direct drive wind turbine generator based on MgB_2 wire has been analyzed in terms of properties, amount of wire needed and expected cost of the active materials. The diameter is 5.8 m and the active length is 3.1 m. A king-pin nacelle concept with the superconducting generator mounted in front of the rotor blades has been proposed, because it is believed to be one of the only ways to support a rotor approaching 250 m for a 20 MW turbine. Finally a cost of capacity analysis of the generator shows that the contribution from the active materials is 226 €/kW, which is lower than the INNWIND threshold of 300 €/kW. Cost reductions imposed by a decreasing wire price indicate that the expenses of the cryogenic cooling systems can be accommodated. This will be further investigated in the INNWIND project and compared with conventional drive trains.

References

1. Innwind.EU project web page: www.innwind.eu
2. B. B. Jensen, N. Mijatovic and A. B. Abrahamsen, "Development of superconducting wind turbine generators," J. Renewable Sustainable Energy, vol. 5, p. 023137, 2013.
3. A. B. Abrahamsen, N. Magnusson, B. B. Jensen, D. Liu and H. Polinder, "Design of an MgB_2 race track coil for a wind generator pole demonstration," in 3P-LS2-07 EUCAS, Genova, 2013.

EWEA 2014 BARCELONA EUROPE'S PREMIER WIND ENERGY EVENT
SINTEF
TU Delft
DNV·GL
INNWIND.EU
SEVENTH FRAMEWORK PROGRAMME